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Implementation of Lock in Amplifier (LIA) for very low signal measurements

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Abstract—In this paper we present the implementation of a lock-in amplifier (LIA) completely based on Labview with a general-purpose data acquisition board (NI 6115 card) and pre-amplifier. The signal analysis of the submerged intelligent signal in noise is processed by the software. We describe some characteristic of the LIA including output voltage vs. frequency. We have also done simulation of signals using LIA based on which signal is locked. The LIA is be used to measure the small signals, even in presence of noise, which is several times greater than the signal itself. Since the signal processing takes place on the computer, the ones can display the waveform – as a time series or power spectrum – as it progresses through the instrument, which makes it an excellent tool for lab.

Keywords- low-level signal, lock in amplifier, phase, amplitude, broadband noise, LAB VIEW.

I. INTRODUCTION

Lock-in amplifier is a modern instrument used for studying the nature closely and clearly with various physical, chemical and biological parameters. A situation exists where one needs to measure the signal whose amplitude is much smaller than the noise component presents in the environment mainly in many scientific and industrial applications. Lock-in amplifier is very essential in such case. In various aspects, low-level signal processing is of practical importance but it is encountered with many difficulties. As the state of the instrument undergoes changes with temperature and time, the measurement result fluctuates. Low-level signal is having low signal-to-noise ratio (SNR). Sources of noise include from the power network, pre-amplifiers, thermal noise and leakage current noise from sensors or a combination of them [1].

Lock-in amplifier filters off all signal parts having different frequencies than the nominal frequency so does not affect the measurement. The PSD equipment not only can detect the amplitude of a signal having the same frequency as the reference signal but also is sensitive to the difference in their phases. Therefore, a system involving PSD can be used in detection of both amplitude and phase of a signal [2].

II. LITERATURE REVIEW

A. Junction Impedance Measurement of Diodes by simplified lock in amplifier

To implement this measurement we have a lock in amplifier, which is suitable for phase detections. Juh Tzeng Lue explained a lock in amplifier, with its extremely narrow equivalent bandwidth, which is capable of measuring a periodic signal buried in noise and is becoming increasingly useful in scientific instrumentation. The fundamental operational principle is that an input signal is demodulated by a synchronous reference signal to produce in-phase or out-of-phase signals by a phase-sensitive detector [3].

B. Frequency Domain Description of Lock in Amplifier

The signal to be measured is fed into the input of the AC amplifier. The output of the DC amplifier is a DC voltage proportional to V0. The AC amplifier is simply a voltage amplifier combined with variable filters. The voltage-controlled oscillator is just an oscillator except that it can synchronize with an external reference signal both in phase and in frequency [4].

C. Lock in amplifier response simulation using MathCAD

A lock-in amplifier is a device for the measurement of amplitude of AC signals in the presence of noise. A lock-in amplifier uses a synchronous detector, phase sensitive detector, PSD to improve the signal-to-noise(S/N) ratio in AC experiments. The PSD requires that the signal be modulated at some reference frequency. The lock-in amplifier than amplifies only the component of the input signal at reference signal frequency and filters out all other frequencies. The main components of a lock-in amplifier are 1) amplification system 2) phase shifter 3) multiplier (PSD) and4) low-pass filter 5) modulation system [5].

D. High performance modular digital lock in amplifier

The hardware architecture of this digital lock-in amplifier is based on a VME-bus standard crate, in which commercial VME board are housed. The advantage of such a modular choice becomes plain when the digital LIA will be pact of

more complex digital system within this architecture; the lock-in amplifier is simply made by a CPU board [6].

E. Implementing Digital Lock-in Amplifiers using the dsPIC DSC

The dsPlc33f is a powerful digital signal controller and its capabilities are well suited to both the signal generation and processing tasks in this application. The high speed ADC and DMA allow for a high data throughput, while the efficient DSP engine can perform the multiple filtering stages. The digital lock-in amplifier is useful tool for measuring small signals. By translating the signal measurement to a high frequency. It is possible to avoid noise introduced at DC and low frequencies. It is possible to detect both amplitude and phase changes using the lock-in amplifier, it is possible to measure signal changes caused by devices with complex impedances, such as capacitive sensors perform the phase sensitive detection and filtering [7].

III. PRINCIPLE OF WORK

Lock-in amplifiers are divided into two groups: single phase and dual phase lock in amplifier. Single-phase lock-in requires adjustment of the phases of reference signal and signal to achieve the maximal output signal. Obtained amplitude is what we need to measure. Output amplitude decreases if the phases are shifted. The phase adjustment block is needed here. In the two- phase lock-in, the phase shifts do not play any role.

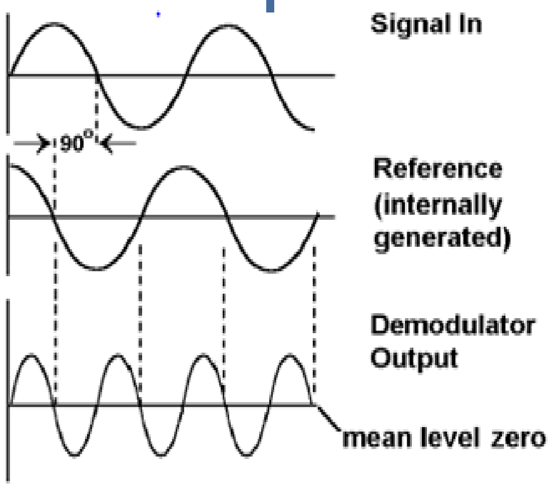

Fig.1.Wave Diagrams

Phase-sensitive detection technique is used for lock in amplifier. Reference and input signal are needed. Reference signal is a sine pulse.

$V_{sig} \sin(\omega_r t + \theta_{sig})$

Amplitude of signal is Vsig. Reference signal is of

$$V_L \sin(\omega_L t + \theta_{ref})$$

Output from PSD has a form:

$V_{psd} = V_{sig} \sin(\omega_r t + \theta_{sig}) * V_L \sin(\omega_L t + \theta_{ref}) = 1/2 V_{sig} V_L \cos([\omega_r - \omega_L] t + \theta_{sig} - \theta_{ref}) - 1/2 V_{sig} V_L \cos([\omega_r + \omega_L] t + \theta_{sig} + \theta_{ref})$ output signal having two frequencies: $(\omega_r - \omega_L)$ and $(\omega_r + \omega_L)$. Signal is filtered by a low frequency filter than the, the output signal is:

$$V_{psd1} = 1/2\, V_{sig} V_L \cos(\theta_{sig} - \theta_{ref})$$

$\theta = \theta_{sig} - \theta_{ref}$. By adjusting the θ_{ref} so that $\theta = 0$, we obtain V_{sig} ($\cos\theta = 1$). Inversely, if $\theta = 90^o$ than the output voltage is 0. The single-phase lock-in provides the output voltage [8]:

$$V_{psd1} = 1/2\, [V_{sig} V_L \cos(\theta)] \approx V_{sig} \cos(\theta)$$

To omit this dependence the further PSD block must be involved. In the second PSD the signal is multiplied with the reference signal being shifted by $\pi/2$ [8]:

$$V_L = V_L \sin(\omega_L t - \theta_{ref} + \pi/2)$$

$$X = V_{sig} \cos\theta,\ Y = V_{sig} \sin\theta,\ R = (X^2 + Y^2)^{1/2} = V_{sig},\ \tan\theta = Y/X$$

IV. SYSTEM DESIGN

The diagram of the system is feature in Fig. 2 explains about the system design. Pre-amplifier, Low pass filter and Phase locked loop PLL are present. Input signal is taken to the pre-amplifier. Amplifying coefficient consider appropriately so that the output signal lies in the range of the providing ADC. Digital signal from ADC is divided into 2 multiplying circuits signal is multiplying with the reference signal of the form sin $(\omega_r t + \theta_r)$, and signal is multiplying with the reference signal of the form sin $(\omega_r t + \theta_r + \pi/2)$. Outputs are given to the low pass filter. This filter eliminates the AC component and retains only the DC one. The filter produces the synchronous output and the filter produces the quadrature. These two parts are input in the calculation circuit, whose outputs are the amplitude and the phase shift. The amplitude may be the maximal amplitude V0 or the effective voltage V_{rms}, the phase shift can be given in radian or degree.

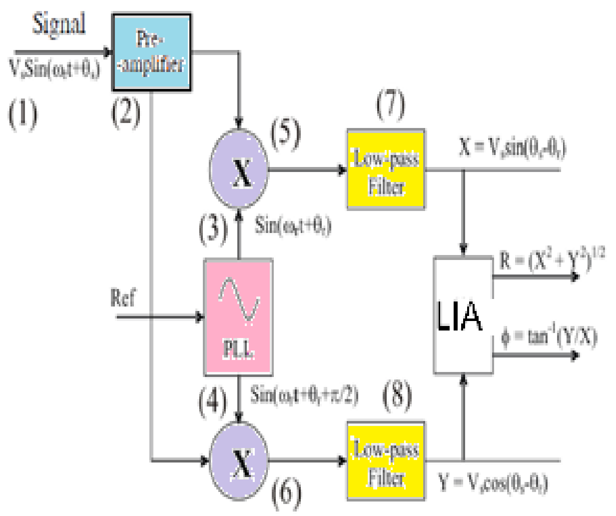

Fig. 2. Schematic diagram of a dual-phase lock-in amplifier

For interfacing NI 6115 card with LabVIEW VI, we need BNC 2110 connector, signal generator, AE sensor, preamplifier for obtaining lock in signal. Input signal is given from the AE sensor and reference signal is generated from the Reference VI. Graphical system design approach is that researchers can use the same technology in the final phase of experimental development, the deployment phase. Researchers can easily transfer the technology to market because the same tools and platforms are used in both the research/development phase in the academic environment and the deployment phase. Research laboratories still have access to a wide variety of legacy, traditional, or specialized bench top / rack-mounted instruments that researchers can easily integrate into a virtual instrumentation system. Instruments have one or more serial/parallel communication ports readily available such as RS232, RS485, RS422, and GPIB. Instruments may also include an Ethernet and/or USB ports [9, 10].

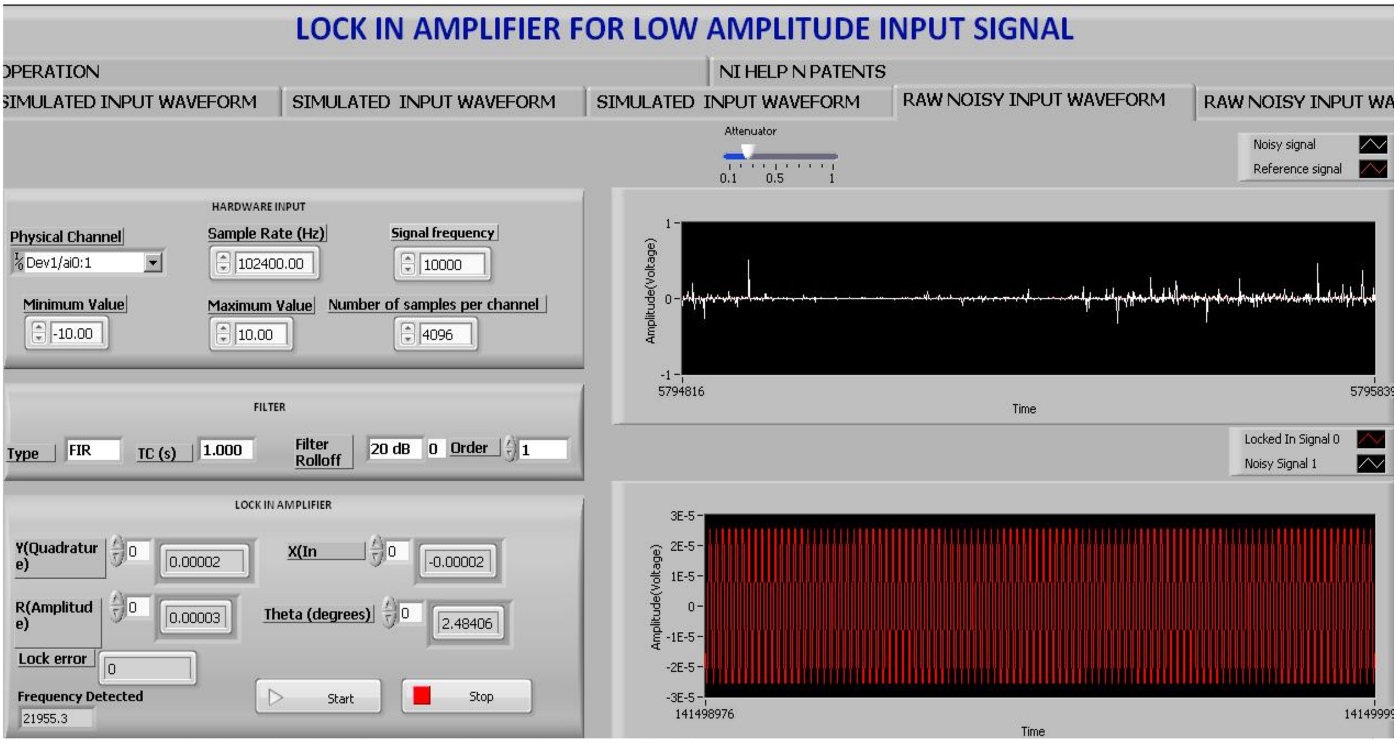

Fig.3.Front Panel of Lock in Amplifier for real signal using DAQ NI 6115 card

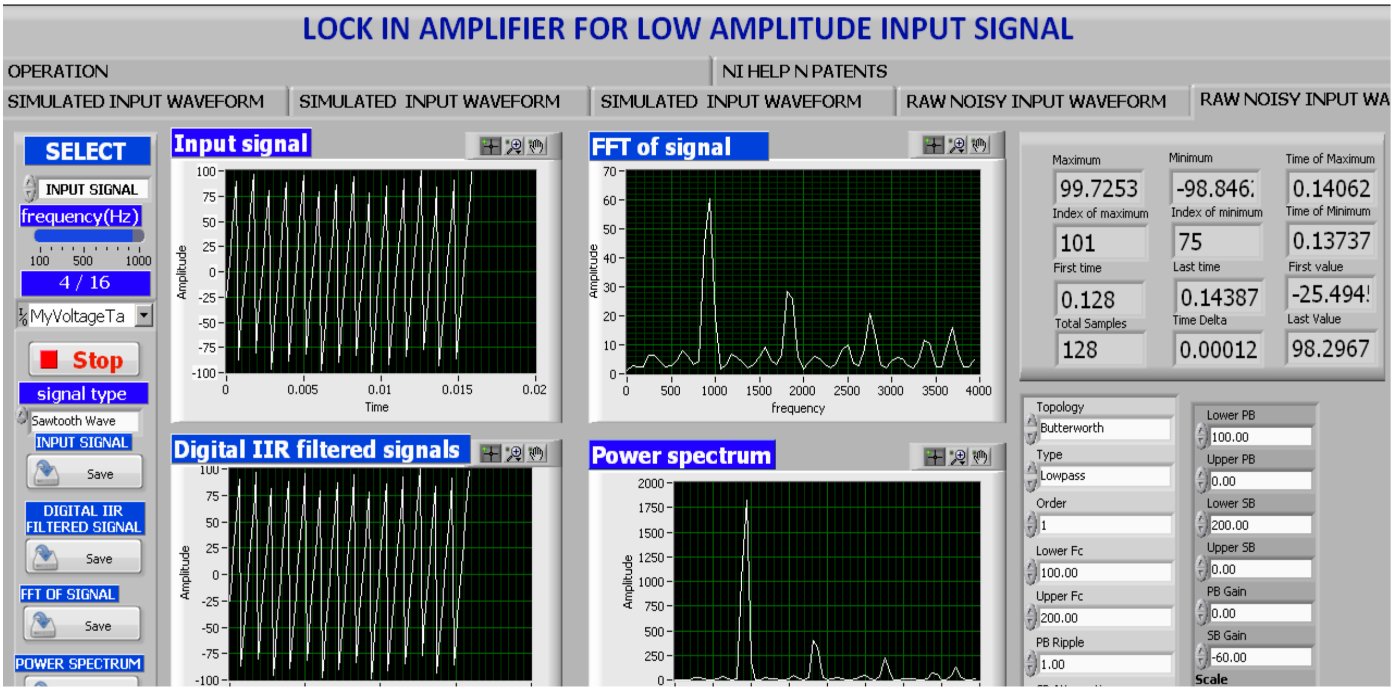

Fig.4.Front Panel of Lock in Amplifier

V. CONCLUSION

Two-phase lock-in amplifier is implemented by only one PC with DAQ card with the pre-amplifier. It is easy to implement this device in the laboratories. Its functionality is adaptable for very low-level signal. The design characteristics can be easily modified for various kinds of experiments. The data processing is automatic and convenient and is saved directly to disks. The further important application is that it is used as a teaching tool. Since the system uses Labview, it is easy to control and to evaluate the signals at every its segments so provides clarity for users to understand the working of the lock-in amplifier. It is used for Non-Destructive Testing in Heat Exchangers for sensing Acoustic Emission waves. There is flexibility and different options of different types of frequencies. In comparison with hardware based lock in amplifier many types of filters are required to be designed where as in LabVIEW Express filter VI block is considered for designing many types of filters with ease of design. It also gives a visual impact [11,12].

VI. FUTURE SCOPE

For different ranges of signal frequencies, modified lock in amplifier can be developed by using this technique All the VIs (Virtual instrument) developed have been implemented using simulated input signals. All of them can be implemented in real time as well with the help of a fast sampling DAQ card such as NI PCI 6115 DAQ device, BNC Connector, and an external hardware module for capturing the real signal with noise present in it. The external hardware module is expected to be made up of filtering stages consist of High Precision Pre-Amplifiers to aid to eliminate noise. Lock-in amplifier can be good at signal processing and noise rejection can be raised further there by improves the signal to noise ratio compared to the analog lock-in amplifiers. The ability to display both time series display and frequency domain displays of the signal – to have an arbitrary number of spectrum analyzers and oscilloscopes connected to the signal path – can be of great utility. Furthermore, LabVIEW has powerful simulation capabilities of its own in form of VIs: it cannot only implement the LIA but also can simulate the entire experiment. These features make the PC-based digital lock-in analyzer an excellent tool for lab [13].

REFERENCES

[1] Bhagyajyoti, Immanuel J, L. S. Sudheer, P. Bhaskar, Parvathi C. S.- Review on Lock-in Amplifier, International Journal of Science, Engineering and Technology Research (IJSETR), ISSN: 2278 – 7798,Volume 1, Issue 5, November 2012.

[2] Maxmillano Osvaldo Sonnaillon and Fabial Jose bonetto,-a Low cost high performance digital signal processor based Lock-in amplifier capable of measuring multiple frequency sweeps simultaneously, Review of Sci. Intr. 76, 024703,2005.

[3] Juh Tzeng Lue., — Junction Impedance Measurement of Diodes by simplified lock in amplifier, IEEE, Trans. On Instrumentation and Measurement, vol.IM.26, No. 4,Dec 1977.

[4] John H. Scofield., — A Frequency- Domain description of a lock in amplifier. American Jour of Physics, 62(2), 129-133, Feb 1994.

[5] J.L. Guinon., E. Ortega., J. Gearcia-Antion and V. Perez-Herranz., —Lock-in amplifier Response simulation using MathCAD, Dept. of Ingenieria Quimica y. Nuclear, University of Spain, 53(2), 122-133,Feb 1988.

[6] Fabrizio Barone., Enrico Calloni., Luciano DiFiore, Aniello Grado, Leopoldo Milano, and Guido Russo., ―High Performance Modular Digital Lock-in amplifier, Rev. Sci. Instrum, 66(6), 129-133,June, 1995.

[7] Adrian A.Dorrington and Rainer Kunnemeyer., ―A simple Microcontroller base digital Lock-in amplifier for the detection of low level optical signal, Proc. of IEEE on Inter. Work shop on Electronic Design, Test and Applications,DELTA'02, 2002.

[8] M Gabal., N. Medrano, B. Calvo, P. A. Martinez, S. Celma, M.R. Valero.,―A complete low voltage analog lock-in amplifier to recover sensor signals buried in noise for embedded application, Proc. Eurosensors, Linz, Austria XXIV, Sept. 5-8, 2010.

[9] Tasho Tashev, ―Signal Measuring Instrument Lock-in amplifier, Dept. of Electrical Measurement, Technical University of Sofia, Bulgaria, Rev. Sci. Instrum, 66(6), 129-133,June, 1996.

[10] Philip Kromer, Ralph Robinett, Roger Bengtson, Charles Hays, PC-Based Digital Lock-In Detection of Small Signals in the Presence of Noise, Department of Physics, University of Texas at Austin, Rev. Sci. Instrum, 65(6), 129-133,July 1999.

[11] Implementation of the digital phase-sensitive system for low signal measurement Pham Quoc Trieu*, Nguyen Anh Duc Department of Physics, College of Science, VNU, Hanoi, Vietnam, Sci. Instrum ,68(9),334,17 October 2008.

[12] Coly Crark, Labview Digital Processing, McGraw-Hill Publisher,2005.

[13] Virtual Instrumentation Using Lab View by Sanjay Gupta and Joseph John 2ndedition TMH publication Part II, 36–41, 2006.

[14] LIA-150 Dual Phase Lock-in Amplifier, Becker & Hickl GmbH Nahmitzer Damm Berlin (1999).

[15] MODEL SR830 DSP Lock-In Amplifier, Stanford Research Systems Inc (R2.2 2005).